RESEARCH HIGHLIGHT

May 2009 Technical Series 09-105

Understanding Vapour Permeance and Condensation in Wall Assemblies

INTRODUCTION

The use of low-permeance polyethylene sheets (6 mil polyethylene) as a combined air and vapour barrier is well integrated into building codes and the Canadian construction industry, as a result of significant investment in research and training. Their use as air barriers has resulted in an improvement in building envelope air tightness when properly detailed. Contractors and inspectors have developed a good understanding of the details and practices required to achieve air-tightness in housing. However, there have been concerns that polyethylene vapour barriers may reduce or eliminate drying to the interior and exacerbate summer condensation and hence the appropriateness of polyethylene as a vapour barrier has been questioned.

Given the uncertainty that exists in the residential construction industry with respect to this issue, CMHC initiated a research program to investigate the significance or insignificance of potential moisture problems due to the use of low permeance plastic sheeting in above-grade and below-grade wall assemblies. The research was intended to identify cases where performance could be improved, and provide information on general approaches to help mitigate performance concerns.

BACKGROUND

Air has a limited capacity to hold water vapour: the maximum capacity decreases significantly as the temperature drops. Condensation occurs when the air's capacity at a surface is exceeded and water vapour changes to a liquid. Water vapour moves to a surface by two mechanisms: 1. *vapour diffusion*, the flow of vapour only from regions of high vapour content to regions of low vapour content and 2. *convection or air leakage*, the flow of air from regions of high air pressure to regions of low pressure carrying water vapour along with it. Vapour barriers or vapour diffusion retarders address the flow of vapour by diffusion. Air barrier systems control the flow of vapour by air flow.

Air flow transports much more vapour than diffusion in most cases. Air barrier systems are always required, and can be provided in a number of different ways, for example:

- sealed, continuous and supported 6 mil polyethylene;
- sealed and continuous drywall;
- some sealed, continuous and supported housewrap products, etc.

Air barriers do more than control condensation, they also ensure thermal performance, reduce sound transmission, and help ensure good indoor air quality.

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In walls insulated with vapour permeable insulation (such as fiberglass batt) and no vapour control, water vapour can diffuse to the exterior sheathing and condense. If the condensation is significant enough, and drying is insufficiently fast, the condensation can cause mold, decay, and/or corrosion. To control the amount of vapour transported by diffusion, vapour barriers (for example, 6 mil polyethylene, special paints, aluminum foil) can be used.

In assemblies that are rarely warm or wet, the flow of vapour during drying will generally be towards the outside in Canada. This fact has resulted in the general rule that vapour barriers should be used on the interior of walls in Canada.

However, as vapour diffusion is also the major mechanism available for drying water trapped in a wall assembly, vapour barriers will also reduce the rate of drying. Walls that are exposed to the sun are likely to be warmer on the outside than the inside for some time of the year. Walls in warmer Canadian climates, such as southern Ontario, may experience vapour flow to the interior, especially in air-conditioned homes. Basements are always damp on the exterior side and often cool on the interior. In these cases, drying to the interior may occur if a vapour barrier is not present on the interior. In some cases, the flow of water vapour inward is so powerful that a low-permeance barrier like polyethylene on the inside can result in condensation on the exterior face of this barrier. This condensate can cause mold growth and decay of the framing.

The research project focused on the impacts of cold-weather condensation on exterior sheathing when no vapour barrier was used, and the impact of warm-weather condensation on the vapour barrier when polyethylene was used. In all cases, a functional air barrier system was provided, as this is required in all houses.

METHODOLOGY

The approach taken combined an extensive literature review and field testing of both above- and below-grade walls with parametric hygrothermal computer simulations.

Three types of full-scale walls (north and south duplicates; six walls total) were installed in the University of Waterloo's BEGHut exposure facility. Table 1 describes the wall assemblies chosen to compare poly to latex paint and the impact of insulating sheathing and orientation.

The interior of the hut was maintained at 50% relative humidity and 20° to 21° C year round. This is a high and dangerous interior relative humidity for winter conditions (it will result in extensive and persistent condensation on double-glazed windows), and was designed to cause significant outward wintertime diffusion wetting. The interior temperature is lower than most air-conditioned residential applications in summer (by 2° to 4° C), and this was expected to increase the duration and severity of inward flows and summer condensation problems. Drying of accidental moisture leaks was not considered.

Table 1 Above-grade wall assemblies

Layer	Above-grade wall 1: 2x6 with polyethylene	Above-grade wall 2: 2x6 without polyethylene	Above-grade wall 3: 2x4 with XPS, no polyethylene
Interior finish	½ in./12.7 mm gypsum wallboard w. latex paint	½ in./12.7 mm gypsum wallboard w. latex paint	½ in./12.7 mm gypsum wallboard w. latex paint
Vapour control layer	6 mil polyethylene	None	None
Framing/insulation	2x6 16 in. o.c. with R-20/RSI-3.5 fiberglass batt	2x6 16 in. o.c. with R-20/RSI-3.5 fiberglass batt	2x4 16 in. o.c. with R-12/RSI-2.1 fiberglass batt
Sheathing	½ in./12.7 mm OSB	½ in./12.7 mm OSB	1 in./25 mm extruded polystyrene R-5/RSI 0.9
Water resistive barrier	Spun-bonded polyolefin (SBPO) housewrap	Spun-bonded polyolefin (SBPO) housewrap	Spun-bonded polyolefin (SBPO) housewrap
Drainage cavity	1 in./25 mm space; bottom vents only	1 in./25 mm space; bottom vents only	1 in./25 mm space; bottom vents only
Cladding	Single wythe brick veneer	Single wythe brick veneer	Single wythe brick veneer

Table 2 Internally-insulated basement wall assemblies

Layer	Below-grade wall 1: 2 in. XPS	Below-grade wall 2: vinyl fiberglass roll blanket	Below-grade wall 3: 2x4 with polyethylene	Below-grade wall 4: 2x4 without polyethylene
Interior finish	½ in./12.7 mm gypsum wallboard w. latex paint	Polyethylene roll blanket facing material	½ in./12.7 mm gypsum wallboard w. latex paint	½ in./12.7 mm gypsum wallboard w. latex paint
Other	19 mm / 3/4 in. airspace and furring strips	None	6 mil polyethylene	None
Framing/ Insulation	2 in./50 mm extruded polystyrene (XPS) R-10/RSI 1.8	R-12/RSI-2.1 fiberglass roll blanket	2x4 16 in. o.c. with R-12 /RSI-2.1 fiberglass	2x4 16 in.o.c. with R-12/ RSI-2.1 fiberglass

In Phase II of this research, a second year of monitoring was undertaken with changes to some of the wall systems. The above-grade walls without polyethylene had a vapour barrier paint applied to the drywall, providing a theoretical resistance of about 50–100 metric perms (or 1-2 US perms). As well, the brick drainage cavity of the walls with polyethylene had the mortar joints at the top of the walls opened up and the insect screens removed from the bottom vents to increase airflow behind the brick veneer.

Four internally-insulated basement wall insulation assemblies were constructed and monitored in a house in Kitchener, Ontario. Installation and instrumentation were completed in the first year of service; the test walls are roughly south facing. The poured concrete basement wall assemblies are detailed in Table 2. The basement was newly constructed and no liquid water penetration problems were observed. The interior conditions in the basement were not tightly controlled, but the measurements indicated that interior moisture levels were about average (based on previous CMHC survey of basement conditions).

All of the walls were instrumented with moisture content, condensation, temperature, and relative humidity sensors. Data was collected at five-minute intervals and the hourly average results stored for analysis. Full weather data were also collected.

The hygrothermal simulations extended the results of the field measurements. The WUFI program was first shown to be capable of predicting the measured above-grade wall results well and then was used to consider a range of different interior humidity levels and exterior climates (St. John's, Newfoundland, Edmonton, Alberta and Vancouver, British Columbia).

RESULTS

Theory and previous research were summarized in the literature review. This confirmed that the need for vapour barriers depends on the interior humidity levels, the exterior temperature, and the makeup of the wall assembly.

The field monitoring of above-grade walls physically demonstrated and confirmed theory and experience: first, the presence of a polyethylene vapour barrier reduces the potential for wintertime diffusion condensation and moisture damage of the wall cavity at high interior relative humidity (50%) conditions. However, the presence of the polyethylene increased the duration and intensity of summertime condensation in the stud bay cavity when using an absorptive cladding and relatively cool indoor conditions (20° - 21° C). In the no-poly north facing walls, mold was found growing on the OSB sheathing and the south-facing poly wall exhibited mold and significant staining on the interior of the framing lumber, particularly at the bottom (Figure 1).

Figure 1 Stain-free south-facing no-polyethylene (left) and mold spots on north-facing no-polyethylene wall

The south-facing wall with extruded polystyrene foam sheathing had good summertime performance; it showed the greatest resistance to summertime condensation from inward diffusion. However, the thermal resistance of the insulated sheathing was insufficient to avoid winter condensation and subsequent moisture run down on the north-facing side under the test conditions: at least 1.5 in. (38 mm) would be needed for 50% interior RH in Toronto. Figure 2 shows some of these results.

All of the south-facing walls benefited from solar heating in winter which increased the weekly and monthly average temperature of the sheathing. This heating was sufficient to essentially eliminate the risk of cold weather condensation.

As noted above, the operating conditions of the test hut were chosen to challenge the walls: under more normal operating conditions, problems will be reduced or eliminated. However, colder conditions, such as in Edmonton or further north, will cause more condensation wetting in walls with latex paint and no polyethylene unless the interior humidity is controlled to lower (and hence safer) levels.

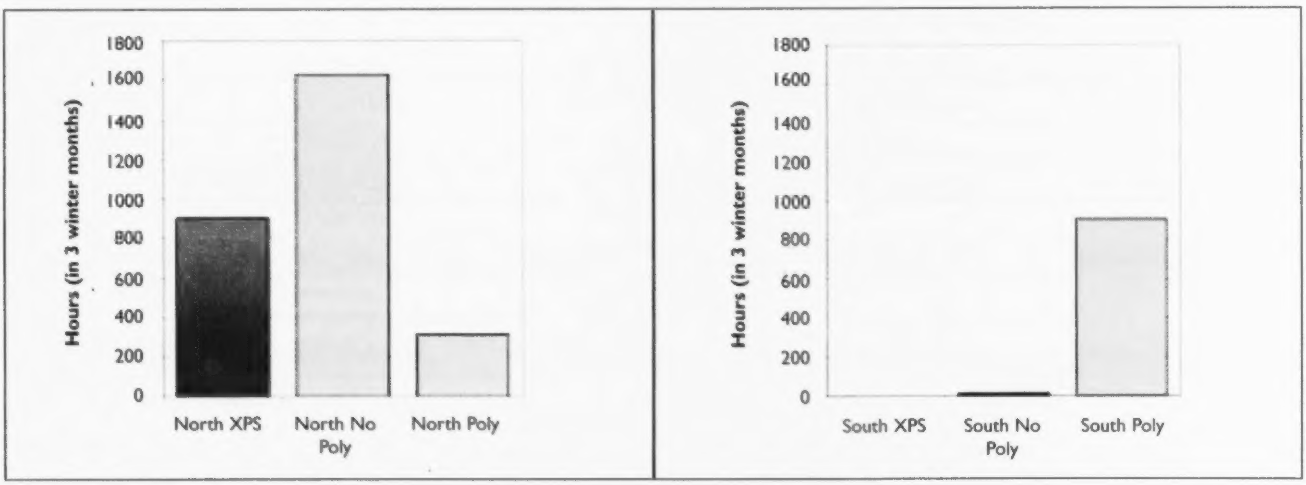

Figure 2 Hours of Condensation Risk Measured in North (left) and South Walls (right)

In Phase II, under similar internal conditions and outside weather, the walls behaved differently. OSB sheathing moisture content stayed below 15% through the winter in the standard 2x6 walls without a polyethylene vapour barrier due to the interior application of vapour barrier paint. See Figure 3. For summer conditions, the provision of a ventilated cavity behind the brick reduced the inward drive that originally caused high humidity at the inside of the drywall on wall no.1 with the polyethylene. The wood wafer moisture content monitor at that location indicated suitably low cavity relative humidities.

None of the below-grade assemblies exhibited signs of major damage, despite the presence of summer condensation in the walls with polyethylene. The no-poly wall showed no signs of condensation or moisture staining. Summer condensation was particularly severe on the roll blanket wall (no. 2). For the monitored period, this condensation did not result in mold or staining, but this might not hold true for longer periods or finished assemblies incorporating these details. The foam wall (no. 1) maintained the wood framing at stable and safe moisture contents, and will help avoid air leakage condensation. Note that the space between the concrete and foam must be carefully air-sealed to avoid connecting this high humidity zone with the interior air.

IMPLICATIONS FOR THE HOUSING INDUSTRY

Regardless of the vapour permeance of the materials used in a wall assembly, control of air flow through the enclosure must be provided by an effective air barrier system. Inadequate control of airflow remains by far the most significant source of condensation for both above- and below-grade assemblies.

Theory and previous research have confirmed that the need for vapour barriers depends on the interior humidity levels, the exterior temperature, and the makeup of the wall assembly. The field testing and simulation results from this study show that low permeance interior layers are required to help control moisture conditions in wall assemblies in some situations but may exacerbate moisture conditions in others. Under conditions of high interior humidity and very cold exterior temperatures, mineral fiber insulated walls with no insulating sheathing will require low permeance vapour barriers such as polyethylene sheet membranes. In applications with lower ("safer") RH (relative humidity) levels, warmer Canadian climates and walls with exterior insulated sheathing, ordinary latex paint may be sufficient. The addition of insulating sheathing controls both cold weather and warm weather condensation without the use of plastic sheeting, but the

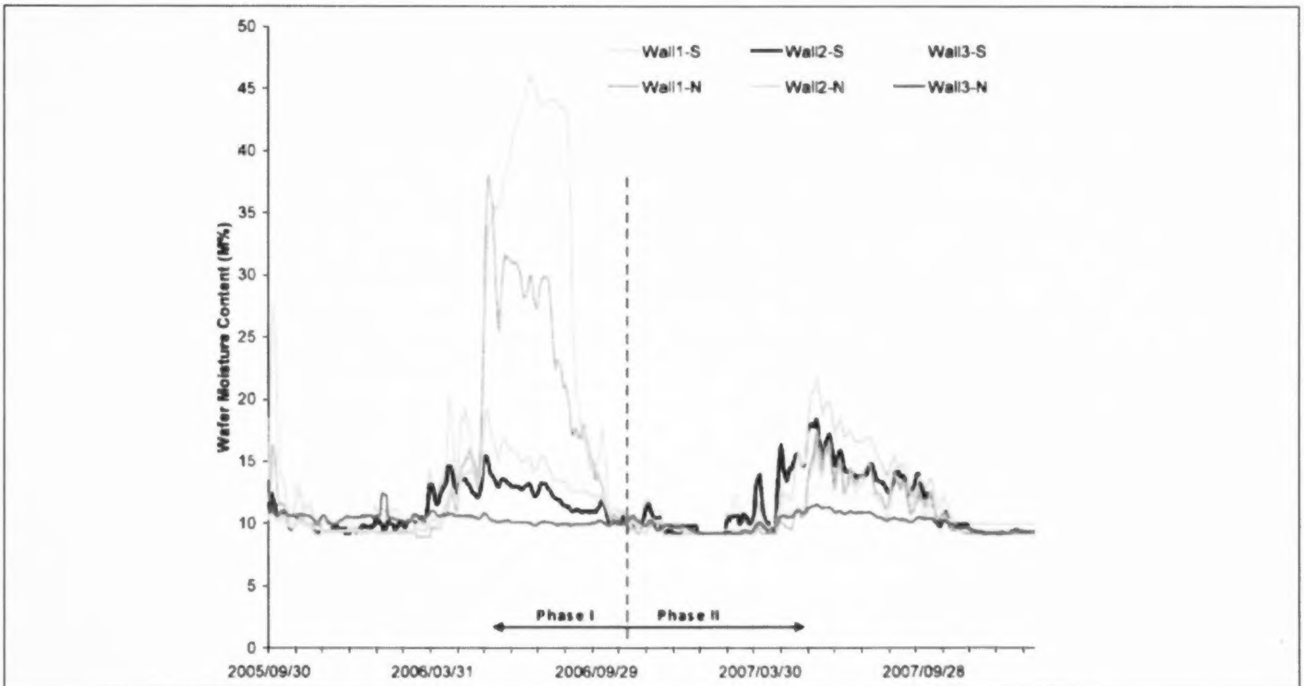

Figure 3 Wood Wafer Moisture Content at Exterior of Drywall

R-value of the insulation must be sufficient to control winter-time condensation for the interior humidity expected. The report provides more detail on what combination of climate, interior RH, and insulated sheathing controls cold weather condensation.

Warm weather condensation on plastic sheet vapour barriers can occur in air-conditioned buildings with a rain-wetted absorbent cladding exposed to the sun. However, this specific and persistent combination of factors is required before condensation occurs. In Phase II of the research, it was found that better ventilation of the brick veneer cavities minimized the effects of inward moisture drive, and kept the walls with polyethylene adequately dry.

With respect to the permeance of vapour barriers, Phase I of the study first tested only 6 mil polyethylene sheets (3.5 metric perms) and latex paint (300 to 600 metric perms): this is a range of permeance of more than a factor of 100. The Phase II research showed that vapour control paints, with a permeance in the range of 50 to 100 metric perms, adequately protected the test walls from vapour diffusion from the interior during winter conditions.

The study shows that above-grade walls with either polyethylene or vapour barrier paint can be made to work in Canadian environments. It also shows that the performance of either can be compromised under severe environments or without proper attention to details. For foundations with interior finishing, research results illustrated the previously known limitations of polyethylene sheet vapour barriers.

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Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

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